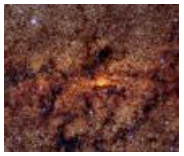
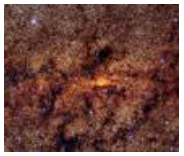


Project completion

High-Performance Cornerstone Technologies for the National Virtual Observatory

PI: Tom Prince, Caltech



Prince, High-Performance Cornerstone Technologies for the National Virtual Observatory

Motivation

- ❖ Deep, wide area imaging surveys have assumed fundamental importance in astronomy.
- ❖ They are being used to address such fundamental questions as the structure and organization of galaxies in space and the dynamic history of our galaxy.
- ❖ One of the most powerful probes of the structure and evolution of astrophysical sources is their behavior with wavelength.
- ❖ However, this power has yet to be fully realized in the analysis of astrophysical images because survey results are published in widely varying coordinates, map projections, sizes and spatial resolutions.
- ❖ Moreover, the spatial extent of many astrophysical sources is much greater than that of individual images.
- ❖ Astronomy therefore has need for a general image mosaic engine that will deliver image mosaics of arbitrary size in any common coordinate system or map projection and at any spatial sampling.
- ✓ Montage aims to provide this service.

High-Performance Cornerstone Technologies for the National Virtual Observatory

PI: Tom Prince,Caltech

Objective

- Deploy a network-based on-demand service (Montage) for the National Virtual Observatory that will deliver science-grade custom sky survey data mosaics from geographically distributed data archives.
- Sustain mosaicking throughput of 30 square degrees per minute (on a 1,024 processor Silicon Graphics Origin 3000 computer system)

Atlas Image mosaic obtained as part of the Two Micron All Sky Survey (2MASS), a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/Caltech

Approach

- Design access and processing architecture and specify client Application Programmer Interface (API)
- Adapt existing mosaic engine to this architecture
- Develop advanced image processing techniques to preserve science information in mosaics
- Optimize throughput and performance of end-to-end distributed system

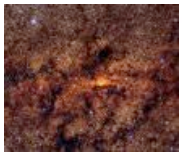
Co-I's

Bruce Berriman,Caltech, Nicholas White,GSFC, Dave Curkendall,JPL

Key Milestones

• API for client access to the image mosaic compute engine defined and published	7/02
• Demonstration of energy conserving mosaic processing with all image rotation projections	2/03
• First demonstration of prototype end-to-end processing using Teragrid Linux cluster	7/03
• 32X processing speedup on Linux cluster demonstrated, including I/O	2/04
• Full interoperability demonstrated using mosaic engine, database server, and 3 datasets	8/04
• Real time performance demonstration at a major astronomy conference	1/05

$TRL_{in}=4$



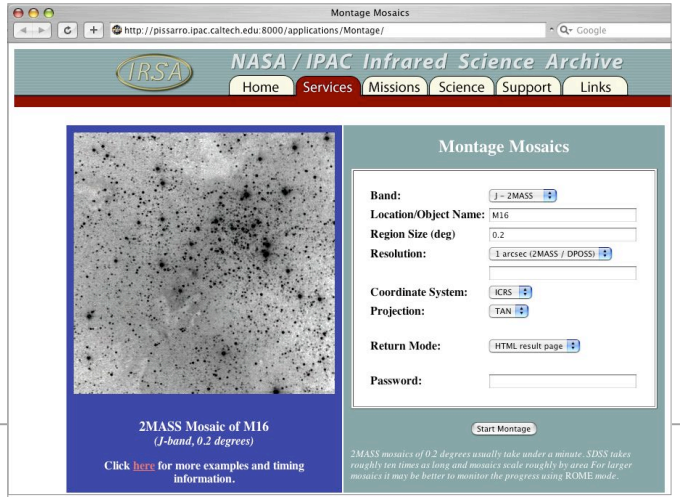
Prince, High-Performance Cornerstone Technologies for the National Virtual Observatory

PI: Tom Prince, Caltech

Objective

- Deploy a network-based on-demand service for the NVO (Montage) that will deliver science-grade custom sky survey data mosaics from geographically distributed data archives.
- Sustain mosiacking throughput of 30 square degrees per minute (on a 1024 O3K system)

The first publicly accessible Montage service is now available on the NASA/IPAC Infrared Science Archive (IRSA) web portal, the archive node for NASA's infrared and sub-millimeter science datasets

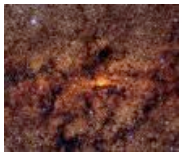


Accomplishments

- Met all objectives
- Montage supports requests for 2Micron All Sky Sky Survey (2MASS), Sloan Digital Sky Survey (SDSS) and Digital Palomar Observatory Sky Survey (DPOSS) image mosaics.
- Technical approach is based on a flexible framework that will support many custom user cases and processing needs.
- Demonstrated ability to build custom mosaics from 2MASS, DPOSS, and SDSS data at the rates of 101, 23, and 32 square degrees per minute, respectively, exceeding the performance milestone goal.
- Demonstrated operational Montage web service at several major astronomical conferences
- Extensive software documentation in line with NASA standards; documented performance scaling curves.
- Montage system, including source code, publicly available at http://montage.ipac.caltech.edu/
- In operation, Montage, in collaboration with the National Virtual Observatory (NVO), will be deployed on the emerging NSF TeraGrid, where it will process requests for 2MASS, SDSS and DPOSS image mosaics; the requests will be made through existing astronomy World Wide Web portals.
- Maintenance of the Montage software will be assumed by IRSA.

Impact *(see following charts)*

TRL=4_{in}-6_{out}



Prince, High-Performance Cornerstone Technologies for the National Virtual Observatory

Montage Science Impacts

- **Spitzer Wide-area InfraRed Extragalactic Survey (SWIRE)**
  - Hi-light
  - –Spitzer Legacy Program
  - –Discovery of new galaxies with redshift z~3
  - –Supporting observations using ground- and space-based telescopes
  - –Different telescopes and image parameters (rotation, projection, pixel scales) => Montage processing images to a common set of parameters

- **The INT/WFC Photometric H-alpha Survey (IPHAS) of the Northern Galactic Plane**
  - Hi-light
  - –Deep H-alpha survey of Southern Galactic Plane in the red (Sloan R and I bands)
  - –Generates large scale mosaics (5 x 5 sq deg) of regions of the galactic plane
  - –Survey of short lived phases of stellar evolution will significantly advance our knowledge of the extreme phases of stellar evolution

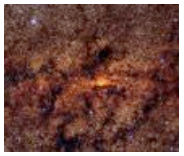
- **Astrogrid (UK component of International Virtual Observatory**
  - –Montage adopted as a "key application" for end users to generate custom mosaics

- **Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE), a Spitzer Space Telescope Science Legacy Program**
  - –Data Product: Image Mosaics of Galactic Plane over 220 sq deg in four colors with the Infrared Array Camera
  - –GLIMPSE is changing our view of the structure of our own Galaxy; e.g.
    - Aug 16 press release - discovery of a bar in our Galaxy 27,000 light-years long (http://www.news.wisc.edu/11405.html)

- **Spitzer E/PO**
  - –Generating large scale mosaics as educational products distributed through the *Cool Cosmos* website
  - –Leverages Montage's capabilities of generating mosaics in uncommon projections, often the best one for E/PO products

- **NASA/IPAC Infrared Science Archive**
  - –Exploits Montage architecture to perform spatial queries on image data sets and return spatial distribution of footprints on the sky
  - –Exploits Montage to generate image mosaic products in bulk for the Spitzer Space Telescope
  - –Generates full sky mosaics for subsetting

- **National Virtual Observatory**
  - –"Hyperatlas grid," a standard set of image parameters for displaying image data sets originally in different projections, coordinates, . . .
  - –Leveraging Montage to deliver tools that will generate map images showing spatial coverage of astronomical data sets



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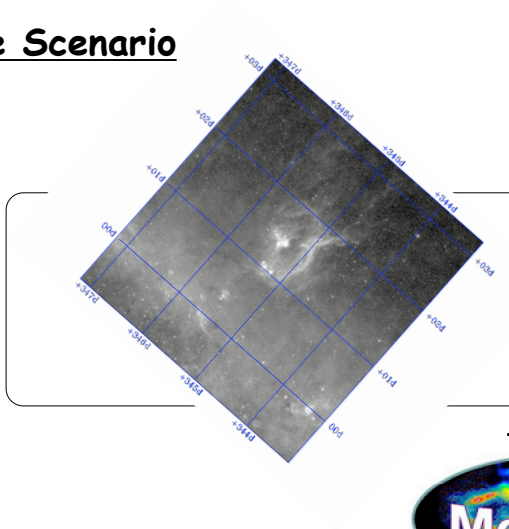
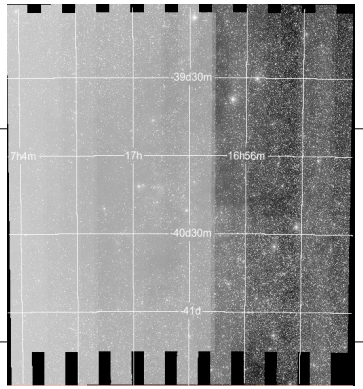
Use Scenario



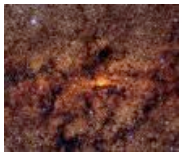
Data co-registered by Montage into a single image:
- *Midcourse Space eXperiment (MSX) data 8.3 μm images - CAR projection (red)*
- *2-micron All Sky Survey (2MASS)-J (green)*
- *2MASS-K - SIN projection (blue)*



Montage

- 3-color mosaic of the star formation region NGC 6357 "War and Peace Nebula" located some 7 degrees west of the center of our galaxy.
- 2.5 degree square mosaic - 9,000 pixels on a side
- In the Tangent projection

The calculation of this image mosaic is the basis of the "How To Use Montage" tutorial, available at http://montage.ipac.caltech.edu/Documentation/2004ADASS/ADASS_2004_MontageDemo.ppt



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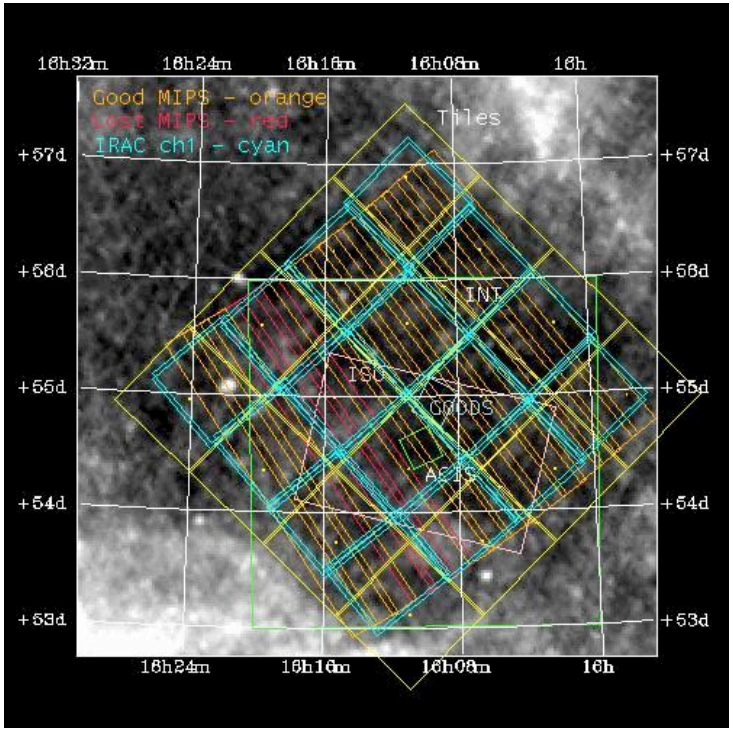
Science Accomplishment

- *The Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE)*
- *Spitzer Wide Area Infrared Extragalactic Survey (SWIRE), and*
- *"From Molecular Cores to Planet-forming Disks" (c2d) teams*

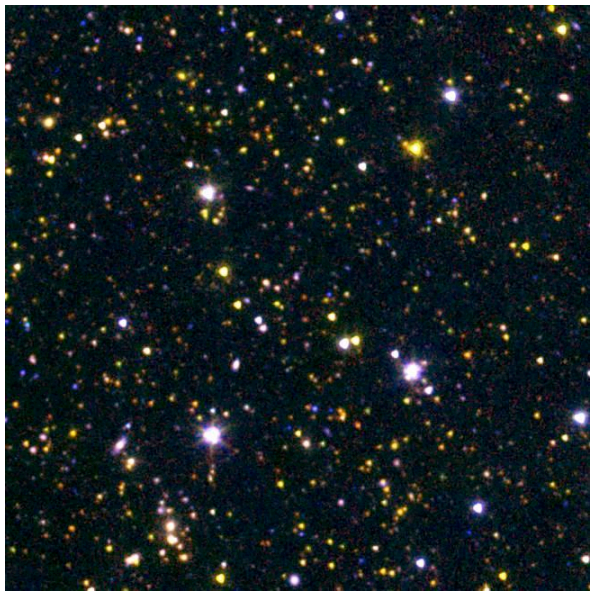
use Montage to support data simulation, mission planning, quality assurance and pipeline development.

Montage support for SWIRE

- SWIRE aims to discover new galaxies at redshifts in the range 2 to 3 by extracting them from Spitzer infrared images and ground-based optical images.
- The images all have different spatial sampling frequencies, projections, coordinate systems and rotations.
- Montage was used as an engine for co-registering these images on the sky on a common spatial sampling and with common instrument parameters, and placing the backgrounds of each set of images on a common level.

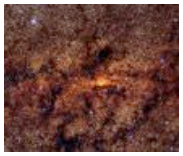


The footprints of the data sets on the sky



A sample science product

White blue objects are stars, but green, red and blue are a new population of galaxies



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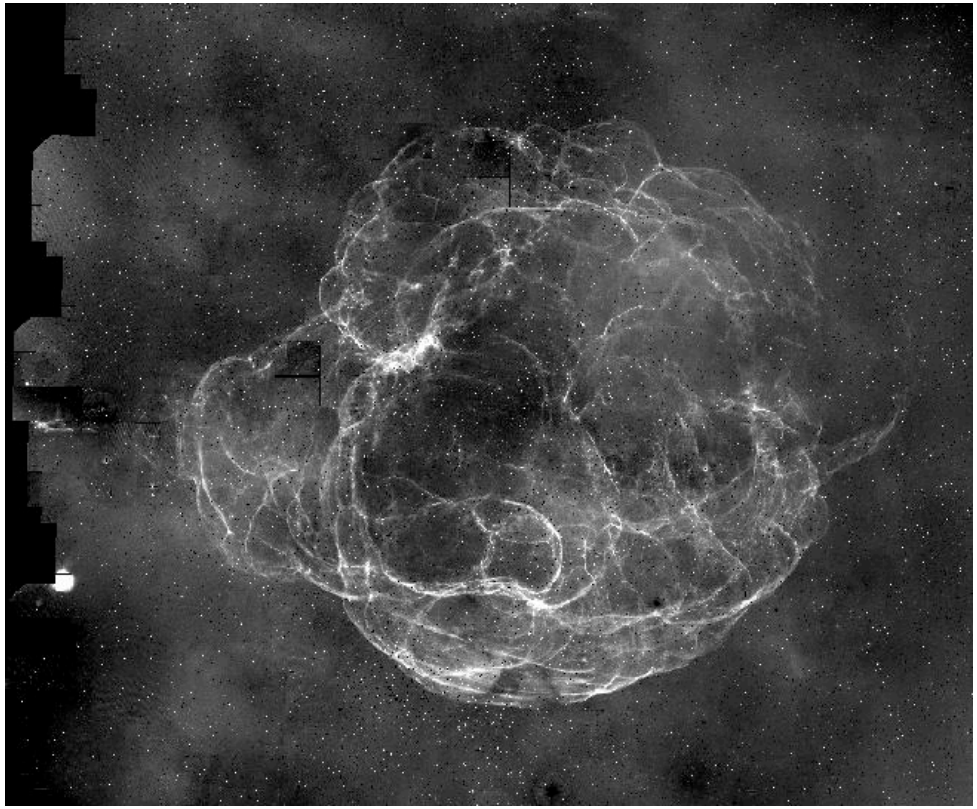
Science Accomplishment

INT/WFC Photometric H-alpha Survey (IPHAS) of the Northern Galactic Plane



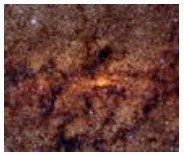
Continuum subtracted Hα image of the supernova remnant S147. This is a very large-scale image, built up by mosaicking a large number of overlapping IPHAS fields together: the total imaged area is roughly 5 x 3.5 square degrees.

In use, Montage proves itself to be a robust, efficient and functional piece of software, well able to handle and process a wide variety of input image data (we have now experience of using it with data from both UK and ESO telescopes).

The documentation set is good.

In the future, I see this as becoming perhaps the premier service for astronomers to use to meet their image mosaicking requirements.

Dr N. A. Walton
University of Cambridge
AstroGrid Project Scientist
European Virtual Observatory
Technology Center Project Scientist



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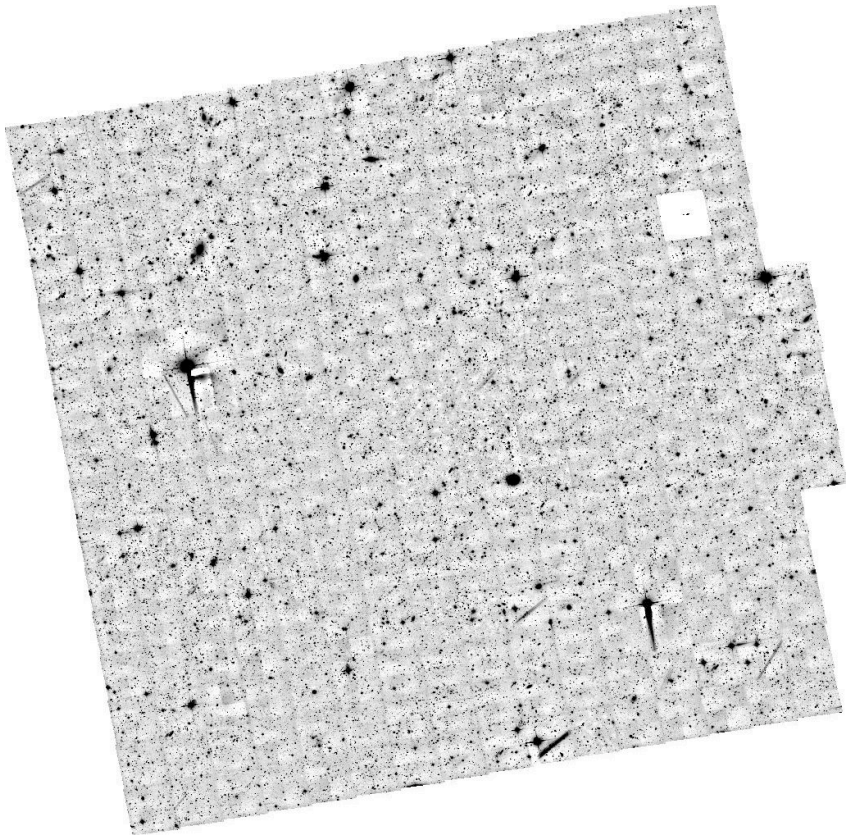
Science Accomplishment



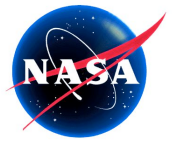
Montage mosaic of 51 I-band images measured with the Hubble Space Telescope (HST) Advanced Camera for Surveys (ACS) to support the science goals of the Hubble Cosmic Evolution Treasury Program (COSMOS).

The output is a 72000 x 72000 pixel FITS image, which is 41GB in size, and is a COSMOS science product deliverable.

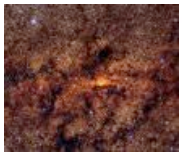
COSMOS is a HST Treasury Project to survey a 2 square degree equatorial field with the ACS camera. It is the largest survey that HST has ever done, utilizing 10% (640 orbits) of its observing time.

COSMOS site:
http://www.astro.caltech.edu/~cosmos/

Public COSMOS data:
http://irsa.ipac.caltech.edu/data/cosmos/



Accomplishment Quad



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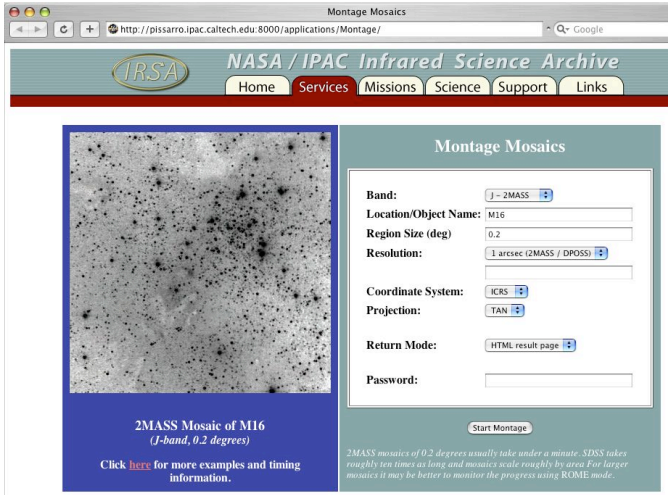

Accomplishments

- Demonstrated operational Montage web service at
  - 14th Astronomical Data Analysis and Software Systems Conference (ADASS), Pasadena, 10/04
  - 205th Meeting of the American Astronomical Society (AAS), San Diego, 1/05
- Demonstrated ability to build custom mosaics from 2MASS, DPOSS, and SDSS data at the rates of 101, 23, and 32 square degrees per minute, respectively, exceeding the milestone goal of 30 square degrees per minute [on a 1024x400Mhz R12K Processor Origin 3000 or machine equivalent]
- Presented scaling curves. Updated documentation.
- Made source code publicly available via the web.

Key Milestones *(11 milestones total)*

H - API for client access to the image mosaic compute engine defined and published	7/02
F - Demonstration of energy conserving mosaic processing with all image rotation projections	2/03
I - First demonstration of prototype end-to-end processing using Teragrid Linux cluster	7/03
G - 32X processing speedup on Linux cluster demonstrated, including I/O	2/04
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$TRL=4_{in}-6_{current}$